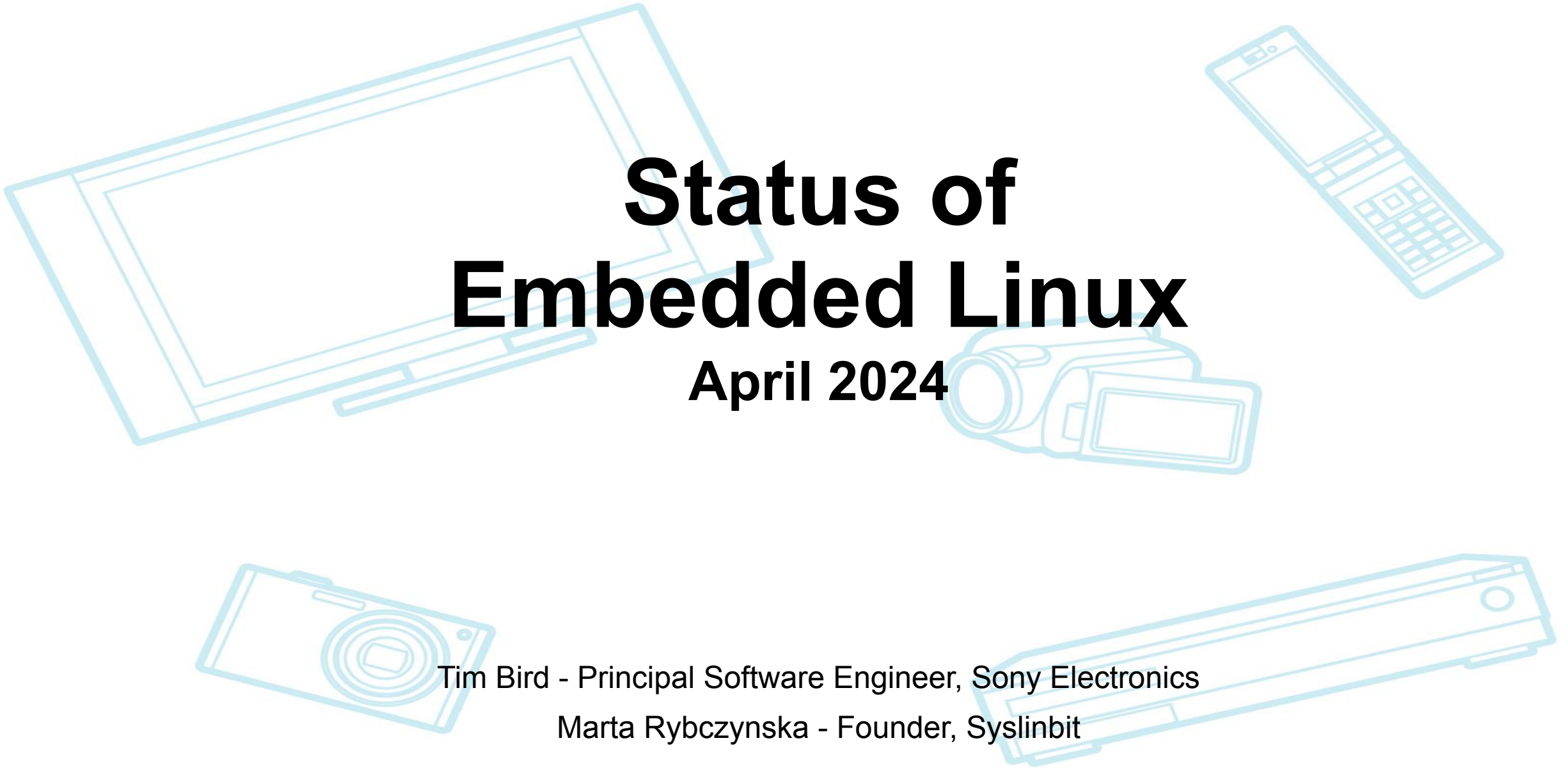


Status of Embedded Linux

April 2024

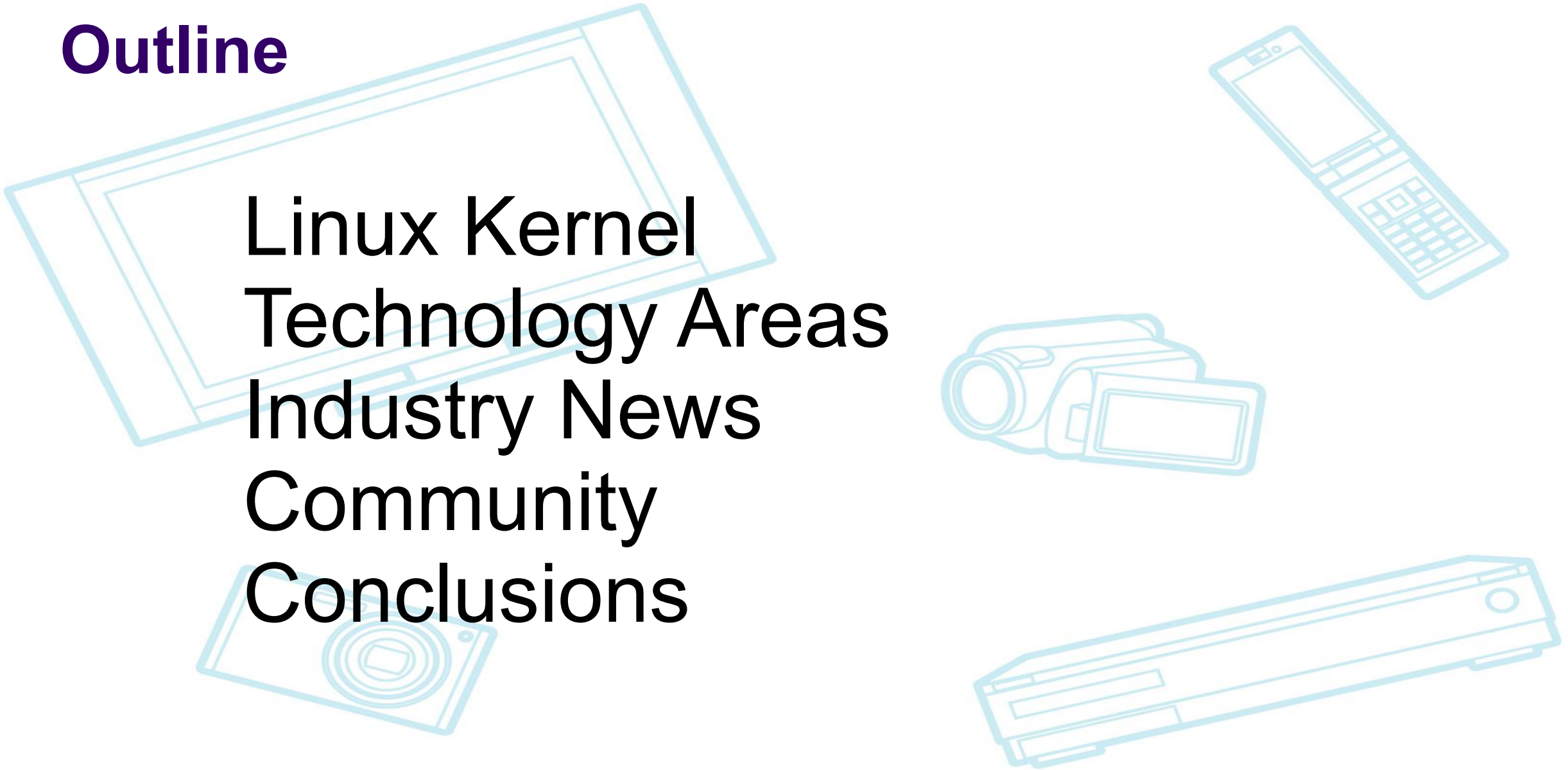
Tim Bird - Principal Software Engineer, Sony Electronics

Marta Rybczynska - Founder, Syslinbit

Nature of this talk…

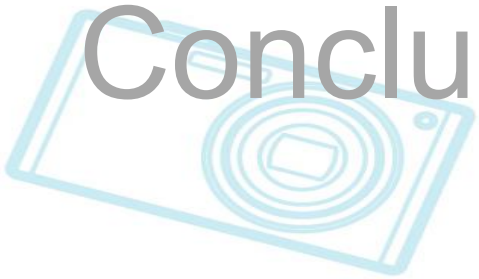
- Periodically take a look at the status of embedded Linux
  - Not comprehensive – just a few things Marta and Tim saw
- No way to cover everything in 35 minutes
  - Sorry if we missed something you're interested in
- There are a few extra slides at the end of the deck, that we won't cover

Outline



Linux Kernel
Technology Areas
Industry News
Community
Conclusions

Outline



Linux Kernel

Technology Areas

Industry News

Community

Conclusions

Kernel Versions

- Linux v6.4 – 25 Jun 2023 – 63 days
- Linux v6.5 – 27 Aug 2023 – 63 days
- Linux v6.6 – 29 Oct 2023 – 63 days
- Linux v6.7 – 7 Jan 2024 – 70 days
- Linux v6.8 – 10 Mar 2024 – 63 days
- Linux v6.9-rc4
  - Release expected around 12 or 19 of May

Linux v6.4 (June 2023)

- The SLOB memory allocator was removed
- Some nice documentation added for building the kernel
  - https://docs.kernel.org/admin-guide/quickly-build-trimmed-linux.html
- MODULE_LICENSE() declarations were removed, for code that cannot be built as a module
  - See https://lwn.net/Articles/927569/
- User trace events (API fixes) was merged
  - See https://lwn.net/Articles/927595/

Linux v6.5 (Aug 2023)

- Parallelize bringing up CPUs, reducing time to get all processors online
  - But only on X86, for now
- There was a big reorganization of 32-bit devicetree file directory structure
  - To match arm64, mips and riscv
  - See commit 6c1561fb
- Miscellaneous ftrace and perf updates
  - See https://lwn.net/Articles/937006/

Linux v6.6 (Oct 2023)

- Can now build a kernel without buffer-head support
  - Some buffer head functionality can be replaced by iomaps (and folios)
  - Part of an effort to eliminate the buffer head subsystem
    - See https://lwn.net/Articles/931809/
    - This might lead to older filesystems (that depend on the buffer cache) being deprecated
- New 'eventfs' subsystem
  - Improves memory efficiency of the tracing subsystem
    - Only allocates inodes and dentries for tracepoints when they are needed
- Shadow Stacks (on Intel, for now)
  - See next page

Shadow Stacks

- Provides an alternate stack for return addresses (only)
  - Return address is put on regular stack AND on shadow stack
  - Often managed by hardware, for speed (and security)
  - On return, shadow stack is used to detect if the return address on the regular stack has been altered
    - VERY useful for detecting return-oriented programming (ROP) attacks, which are a major source of security threats
- x86 support landed in 6.6
- Patches for 64-bit ARM and RISC-V are in development
  - See https://lwn.net/Articles/940403/
- Work on shadow stack support in MUSL C library has started

Linux v6.7 (January 2024)

- Can enable or disable 32-bit emulation on x86-64 kernels on the kernel command line
  - Can reduce attack surface
- ia64 (Itanium) architecture removed
- More efficient kernel samepage merging
  - See https://docs.kernel.org/admin-guide/mm/ksm.html
- Printk now supports per-console locking
  - Allows high-priority message output to take over console from lower-priority message
  - https://lwn.net/Articles/909980/

Linux v6.8 (March 2024)

- 'deadline servers' added
  - Prevents realtime tasks from completely starving normal tasks
- The first real RUST driver was added to the kernel
  - A reference driver for Asix PHYs
- Networking core data structures were refactored for better cache efficiency
  - Improving TCP performance in some situations up to 40%
- The SLAB memory allocator was removed (!!)
  - SLUB is the last one remaining in the kernel
- perf data-type profiling was added

deadline servers (for less deadly RT)

- Provides a way to prevent realtime tasks from starving normal tasks
  - Allows an admin to fix a "runaway realtime task" problem
  - Replaces realtime throttling feature
- Added in Linux v6.8
- How it works:
  - Deadline scheduling priority is higher than RT priority
  - A deadline server is set up to be started when possible normal task starvation is detected
  - The deadline server runs normal tasks, within it's guaranteed scheduling quanta (e.g. 5%)
- See https://lwn.net/Articles/934415/

perf data-type profiling

- Adds a new sub-command to perf
  - perf annotate –data-type
  - perf annotate –data-type={field-name}
- Can get sample data per-field in a data structure
- Shows offset of structure fields and frequency of access
- Is very useful to see if shuffling the fields in a data structure might (or did) improve cache performance
  - Can check if a frequently accessed field is in a different cache line
  - Or if all frequently accessed fields are in the same cache line
- See https://lwn.net/Articles/955709/

Linux v6.9 (expected May 2024)

- ext2 file system marked as deprecated
  - Still handed by the ext4 module
- Timer subsystem rework
  - Change the way to manage the CPU for an expired timer
  - See https://lwn.net/Articles/913568/
- Work on reducing network stack contention
- The kernel energy model can be updated at runtime
- Mitigation for “Register File Sampling” vulnerability on Intel Atom

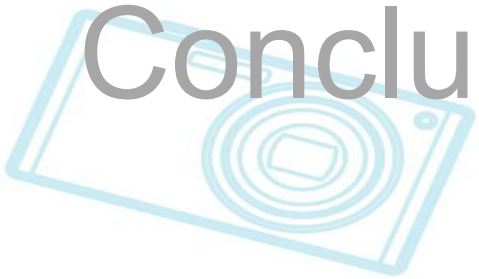
Long Term Supported Kernels

- 6.6 is the latest long-term support (LTS) kernel
  - Current LTS kernels are: 4.14, 4.19, 5.4, 5.10, 5.15, 6.1, and now 6.6
- Plan is to pick one per year, and only maintain for 2 years
  - This is a reduction from the previous plan to maintain for 6 years
  - As support expires for older LTS kernels, they will not be replaced as soon
    - Will reduce the number of supported LTS kernels from 6 to 2
- If you need longer support, get kernels from CIP or Ubuntu LTS
  - Both of these plan to support kernels for 10 years
  - Or consider switching kernels during device's lifetime
- See https://www.zdnet.com/article/linux-kernel-6-6-is-the-next-long-term-support-release/

Contributions by embedded Linux companies (to kernel)

Company	Commits since April 2023	Top contributor	Work area(s) (of top contributor)
Baylibre	227	David Lechner	AD2S1210 driver, spi stuff
Bootlin	455	Miguel Raynal	mtd rawnand, nvmemm, mac802154 driver
Collabora	757	AngeloGioacchino Del Regno	mediatek processor support, panfrost GPU
Ideas On Board	366	Laurent Pinchart	12c, camera, media drivers
Igalia	125	Maíra Canal, Melissa Wen	drm GPU driver
Linaro	4815	Krzysztof Kozlowski	sound, device tree, Samsung clocks
Linutronix	666	Thomas Gleixner	timers, printk, x86, preempt_rt
Pengutronix	2319	Uwe Kleine-König	driver cleanups (remove callback returning void)
Toradex	86	Francesco Dolcini	drm bridge fixes
Wind River	78	Ovidiu Panait	sahara crypto driver

Outline



Linux Kernel

Technology Areas

Industry News

Community

Conclusions

TI Boot time ideas

- Texas Instruments (TI) presentation on automotive boot time
- Ideas:
  - Customize bootloader to avoid duplicate device initialization
    - But must support safety requirements
    - Maybe parallelize parts of u-boot
  - Standardize method to handoff an MCU-initialized device to Linux
    - Specialized MCUs are used to start hardware before Linux boots
    - But then a handoff is needed from MCU firmware to Linux
  - Open ethernet MAC in driver probe
- Presentation: "Resolve and standardize early access to hardware for automotive industry with Linux"
  - by Khasim Syed Mohammed at LPC 2023
  - See https://lpc.events/event/17/contributions/1499/

Graphics – GPU work

- Open Source Vulkan driver for NVIDIA hardware
  - Read for prime time
  - Announced by Collabora
  - See https://www.collabora.com/news-and-blog/news-and-events/nvk-is-now-ready-for-prime-time.html

Filesystems and I/O

- Some work on MTD spi-nor
  - Enhanced locking to support reads while writing
- EROFS enhancements
  - Caching and speed improvements
- Block IO speedup (coming in v6.9?)
  - Cache time to avoid lookup overhead during issue-side of IO ops
  - Yields about 6% performance improvement
  - See https://www.phoronix.com/news/Linux-Caching-Time-Block-IO

Realtime - PREEMPT_RT - What's left

- What's left in PREEMPT_RT patches out of mainline:
  - this year (2024) (patches-6.8.2-rt11):
    - about 3000 lines of code, affecting 91 files (in 121 patches)
    - 48 printk patches, 18 tty/serial patches, 10 drm
    - A few patches each for ARM, PowerPC, Risc-V
  - Thomas that printk changes are the blocker to allow enabling PREEMPT_RT in the mainline kernel
- See https://mirrors.edge.kernel.org/pub/Linux/kernel/projects/rt/6.8/

Security

- Shadow Stacks
  - New in v6.6 (already discussed)
- Work to remove ELF notes from sysfs
  - Some ELF notes in sysfs included relocated kernel addresses
  - Which defeated KASLR (Kernel Address randomization)
  - See https://lwn.net/Articles/962782/
- BPF raises some interesting security issues (unsurprisingly)
  - Authoritative LSM hooks (ones that can override other security mechanisms) was proposed for BPF, but rejected
  - There has been talk of allowing unprivileged users to run BPF modules
    - Not sure if anything will happen there
  - See https://lwn.net/Articles/929746/

Kernel community – CVE handling

- Linux kernel community becomes a CNA
  - CVE assignment is fraught with issues
    - Sometimes the project members disagrees with the impact and severity assessments of the security researcher
    - CNA (Certified Number Authorities) control CVE assignment for their project
  - See http://www.kroah.com/log/blog/2024/02/13/linux-is-a-cna/
  - Policy summary: assigning CVEs only to fixed issues; invalidating non-vendor specific CVEs released by other CNAs
- Other projects that recently became CNAs: glibc, curl, python

System Size

- SLOB memory allocator removed from kernel (v6.4)
  - Not enough people using it (or reporting that they use it)
  - Was deprecated in v6.2
    - IMHO, 2 releases (5 months) isn't enough time for people to notice the deprecation and object to it
- SLAB memory allocator removed from kernel (v6.8..)
- Only SLUB remains
  - Use CONFIG_SLUB_TINY for small systems

Testing - gitlab-ci pipelines

- CI pipelines proposed for kernel tree
  - Collabora proposes some gitlab-ci testing materials
  - Submitted patches to Linux kernel In January and February 2024
- Interesting set of pipeline files and shell scripts
- Currently supports static checks (smatch and checkpatch)
- If you are using gitlab, this could be quite interesting for your QA department
- See https://www.collabora.com/news-and-blog/news-and-events/patch-submitted-to-introduce-gitlab-ci-pipeline-for-kernel-testing.html

Toolchains - GCC

- GCC 13.2 released July 27, 2023
  - See https://gcc.gnu.org/gcc-13/changes.html
  - LTO (link-time optimizations) has been improved
  - Can now emit diagnostics in the SARIF format and gcc's own JSON-based format
    - SARIF = Static Analysis Results Interchange Format
  - Improvements in the static analyzer
- GCC 14.1 (expected this month) will have more improvements in the static analyzer
  - See https://developers.redhat.com/articles/2024/04/03/improvements-static-analysis-gcc-14-compiler

Toolchains - LLVM

- LLVM 18.1.0 released March 5, 2024
  - See https://releases.llvm.org/18.1.0/docs/ReleaseNotes.html
  - Support for multiple new RISC-V extensions, new ARM processors
  - Better support of C++23 and C23
  - Note: This is the first 18.x release (no 18.0) - this represents a change of versioning scheme
- People are using LLVM for whole distributions, not just the kernel

Toolchain resources

- Presentation: "Toolchain Options in 2023: What's New in Compilers and Libcs"
  - at ELC 2023, by Bernard Rosenkranzer, BayLibre
- Still can use traditional toolchain elements, but there are interesting alternatives:
  - binutils: ld, lld (LLVM), mold linker
    - Mold linker is intended to be much faster (and it is)
    - Support LTO for both gcc and LLVM
  - Compilers: gcc, clang (LLVM), TinyCC
    - Similar performance, some BSPs only on gcc or clang
- See https://elinux.org/images/8/84/EOSS23_-_Toolchain_Options_in_2023_-_What%27s_New_in_Compilers_and_Libcs.pdf and https://youtu.be/Vgm3GJ2ItDA

Toolchain downloads

- Popular embedded configurations available in mainstream distributions
- A wide choice of architectures at https://toolchains.bootlin.com/ (including bfin,nios2, openrisc…)
- GCC-based with options for glibc/musl/uclibc

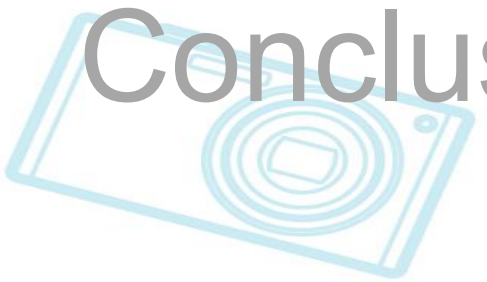
Tracing

- perf data-type tracing (covered previously)
- eBPF
  - Introduction, impact and status (new LF report):
    - https://www.linuxfoundation.org/research/state-of-ebpf
- eBPF is now used for tracing and monitoring (including itself)
  - Netflix releases bpftop for monitoring bpf programs
  - See https://thenewstack.io/netflix-releases-bpftop-an-ebpf-based-application-monitor/

Build Tools and Distros

- Yocto Project
  - Upcoming = 5.0 (Scarthgap), expected April, 2024
    - LTS (Long Terms Support)
    - Support for genericarm64 (SystemReady systems)
    - Default kernel 6.6 (LTS), hundreds of packages updated
  - Latest version = 4.3 (Nanbield), released November, 2023
    - Kernel 6.5 and 300+ recipe upgrades, LLVM 17 support
    - See release notes:
      - https://downloads.yoctoproject.org/releases/yocto/yocto-4.3/RELEASENOTES

Outline



Linux Kernel
Technology Areas
Industry News
Community
Conclusions

Industry News

- Cyber Resilience Act (CRA)
- HDMI Forum preventing creation of open source HDMI driver
- Mars Helicopter

CRA (Cyber Resilience Act)

- Mandatory cyber security framework for software and hardware (including embedded!) in the EU
  - Security updates becoming mandatory (by default 5 years)
  - Due diligence of all components of products (including OSS)
  - Documentation requirements
  - Mostly self-assesment, 3rd party assessment for some categories of products
- Extends the CE marking
- Expected final publication around October 2024
  - Than full application in 2027
  - Details (standards) to be specified during 2024-2027 period

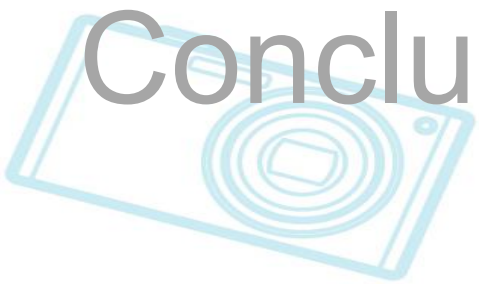
HDMI 2.1 can't have an open source driver

- HDMI Forum told AMD that it can't make an open source driver for HDMI 2.1
  - Means that Linux users can't use highest resolution and frame rates
  - Is a big problem for GPU drivers (which often include audio driver technology for HDMI support)
- Public access to spec has been a problem since at least 2021
  - See https://www.phoronix.com/news/HDMI-Closed-Spec-Hurts-Open
- See https://arstechnica.com/gadgets/2024/02/hdmi-forum-to-amd-no-you-cant-make-an-open-source-hdmi-2-1-driver/

Mars Helicopter

- Mars Ingenuity Helicopter landed in February, 2021 on Mars
- Helicopter blades were damaged on flight 72, on January 18, 2024
  - Helicopter can no longer fly
- NASA announced the end of the mission

Outline



Linux Kernel
Technology Areas
Industry News
Community
Conclusions

Community

- Conferences
- Elinux wiki

Conferences

- Embedded Linux Conference
  - Is now back to twice a year
  - In the spring (April/May) in North America and fall in Europe
    - This one: April 16-18, 2024 in Seattle, USA
    - Next one: Sept. 16-17, 2024 in Vienna, Austria
  - ELC Europe (Vienna) will be a smaller event this year
    - 2 days, 2 tracks
  - Why the change away from EOSS standalone event?
- Embedded micro-conference at Linux Plumbers
  - Also in Vienna, Sept. 18-20, 2024

Elinux wiki

- Linux Foundation hired Bill Traynor as a fulltime employee
  - Will do elinux administration as part of his job
- Site is still used for:
  - Materials for embedded Linux development boards
  - Some academics use it for coursework
  - Event materials: slides and links to videos for ELC
- Some areas of the site are out-of-date
- The site is underutilized for sharing information
- Looking for volunteers to help with the site
- Have set up an LFX Crowdfunding site
  - https://crowdfunding.lfx.linuxfoundation.org/initiative/5fa1a40a-d4f0-4576-81c6-57319a591a87

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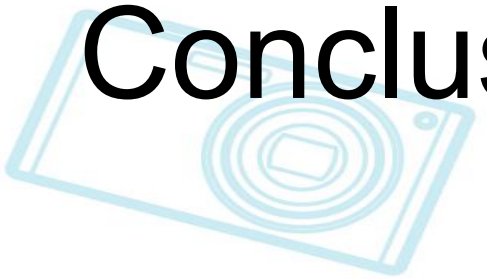
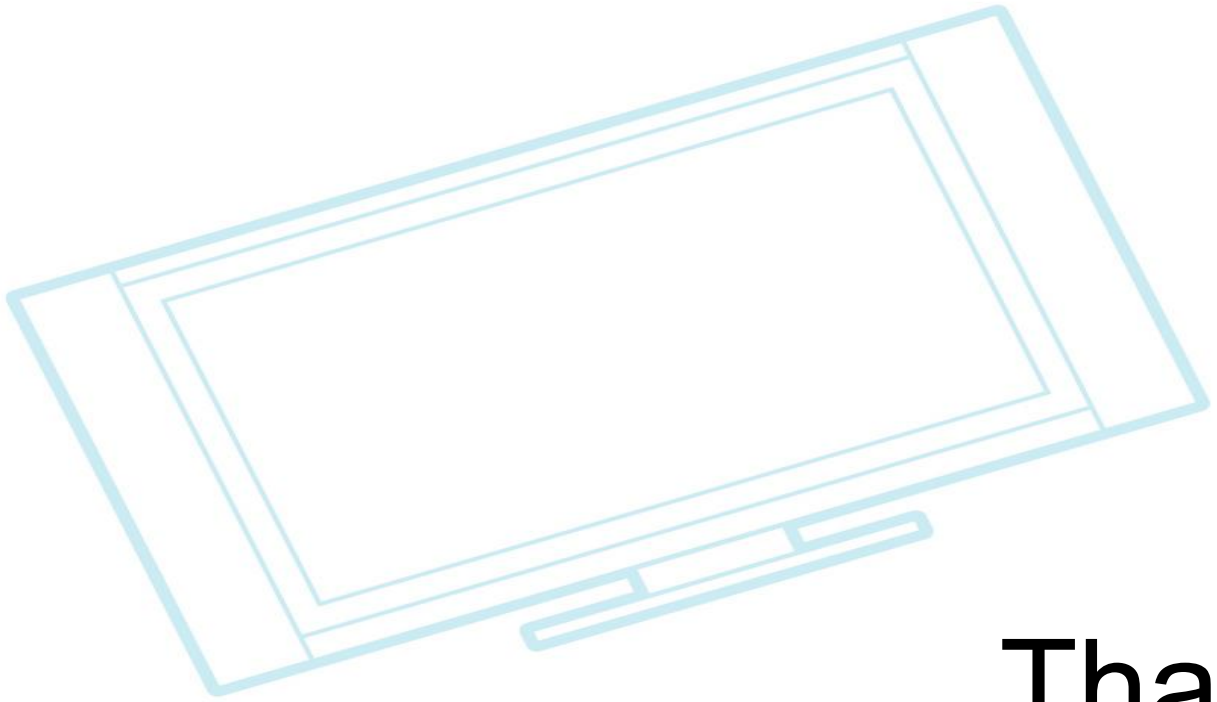


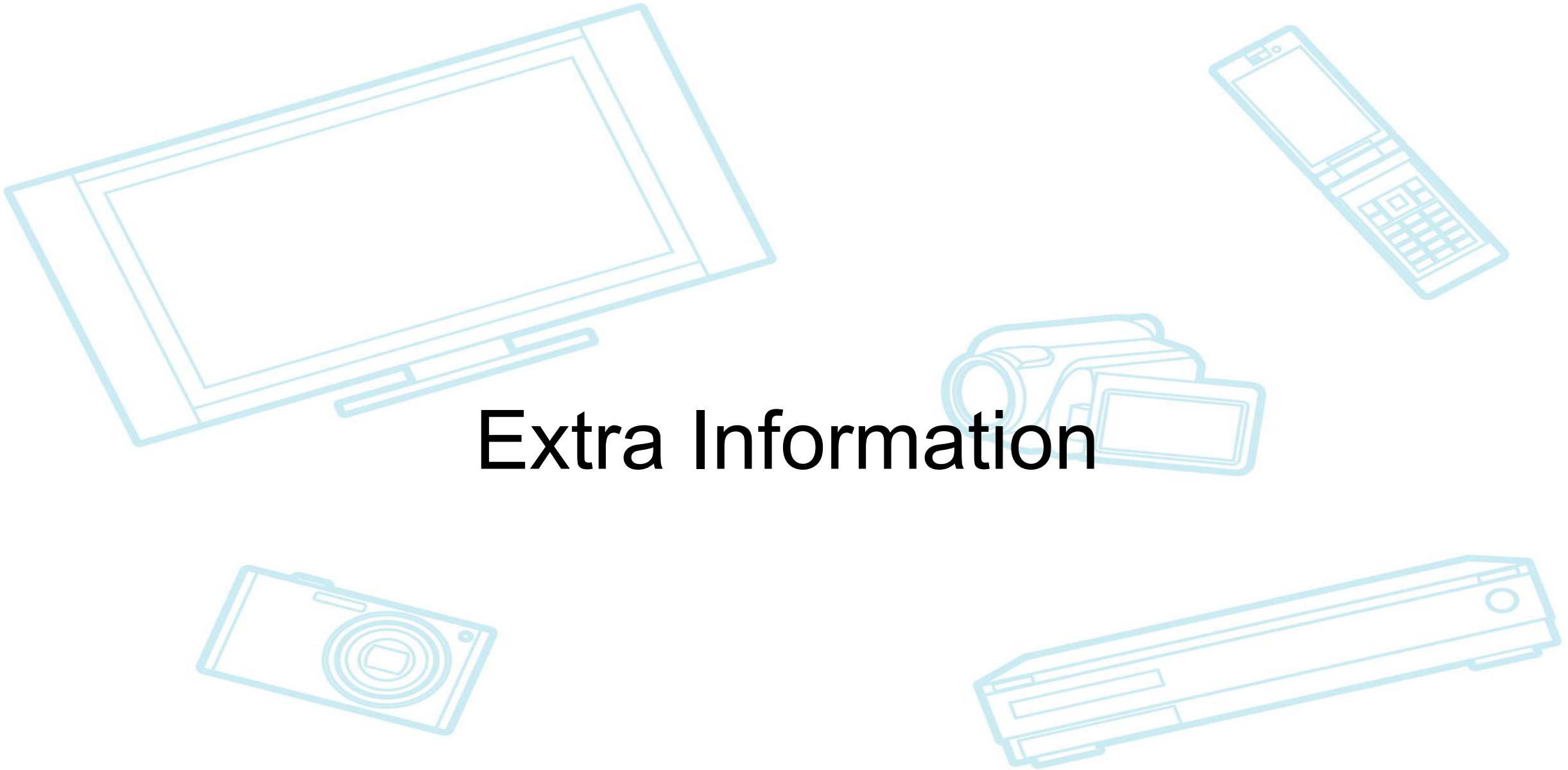
Linux Kernel
Technology Areas
Industry News
Community
Conclusions

Conclusions

- Overall – we're doing very well
  - Embedded Linux is widely deployed and functional (billions of devices)
- Core kernel systems are in place to support embedded
  - But new hardware keeps being made
  - We'll always have things to write and upstream
- More investment is needed by the users of Embedded Linux in the infrastructure and community ecosystem
- What do you think is missing to support embedded development?



Thanks!



Extra Information

Community issues

- Recent discussions in the Linux community about the threat of maintainer burnout
  - This has been a long-term problem
  - Workload is too high, and turnover is very slow
    - Not enough assistant or replacement maintainers
  - Mental health session was provided at LPC for dealing with maintainer stress
  - Also a session with kernel leaders discussing maintainer burnout
    - See https://lwn.net/Articles/952034/
- Similar issues in other projects: see Yocto Project case in https://www.linux.com/news/maintainer-confidential-opportunities-and-challenges-of-the-ubiquitous-but-under-resourced-yocto-project/

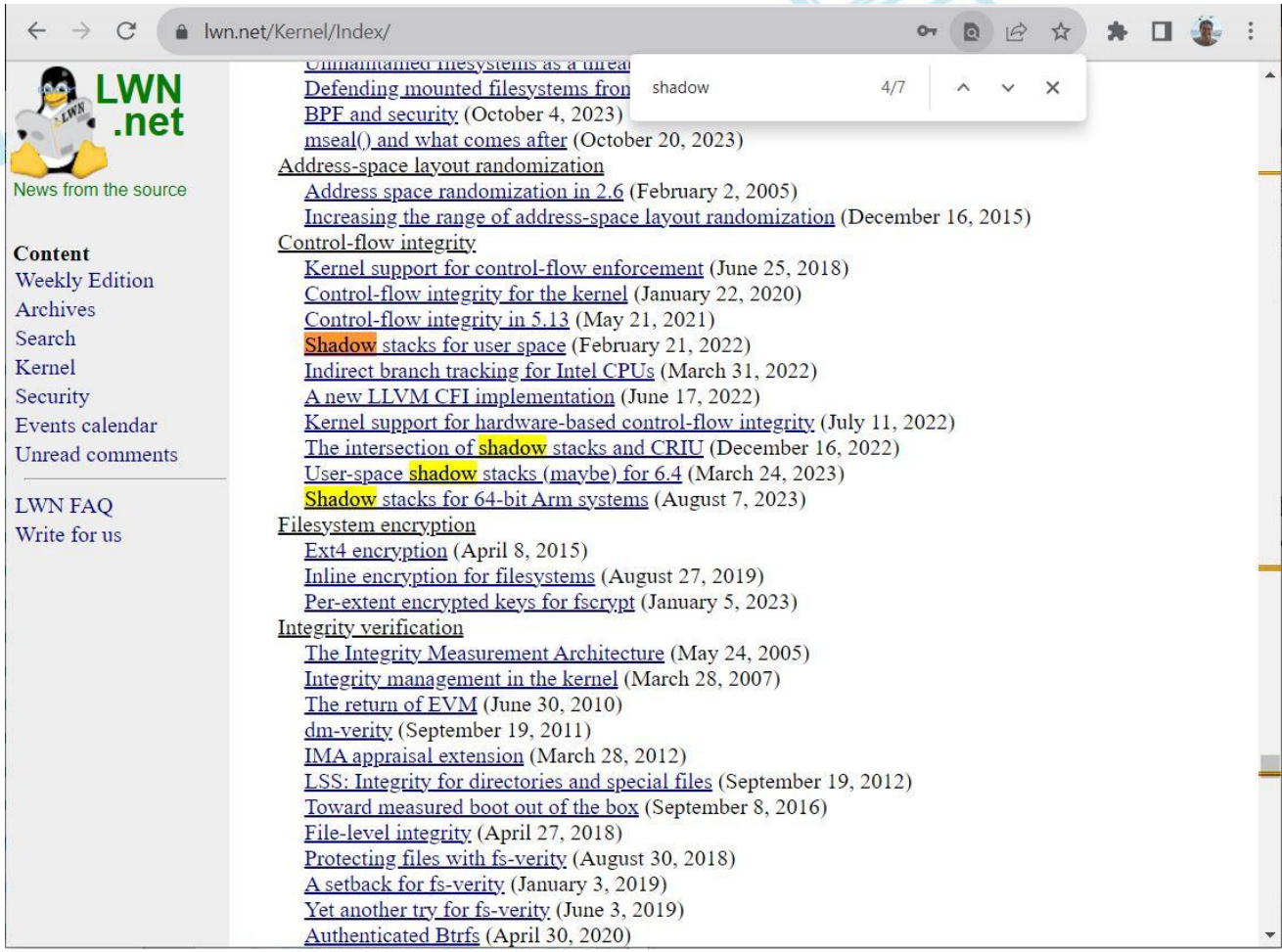
Kernel releases (as of March 2024)

mainline:	**6.8-rc6**	2024-02-25	[tarball]		[patch]	[inc. patch]	[view diff]	[browse]
stable:	**6.7.7**	2024-03-01	[tarball]	[pgp]	[patch]	[inc. patch]	[view diff]	[browse] [changelog]
longterm:	**6.6.19**	2024-03-01	[tarball]	[pgp]	[patch]	[inc. patch]	[view diff]	[browse] [changelog]
longterm:	**6.1.80**	2024-03-01	[tarball]	[pgp]	[patch]	[inc. patch]	[view diff]	[browse] [changelog]
longterm:	**5.15.150**	2024-03-01	[tarball]	[pgp]	[patch]	[inc. patch]	[view diff]	[browse] [changelog]
longterm:	**5.10.211**	2024-03-01	[tarball]	[pgp]	[patch]	[inc. patch]	[view diff]	[browse] [changelog]
longterm:	**5.4.270**	2024-03-01	[tarball]	[pgp]	[patch]	[inc. patch]	[view diff]	[browse] [changelog]
longterm:	**4.19.308**	2024-03-01	[tarball]	[pgp]	[patch]	[inc. patch]	[view diff]	[browse] [changelog]
linux-next:	**next-20240301**	2024-03-01						[browse]

LWN.net Resource for Kernel Information

- LWN.net Kernel Index
  - Has many years of articles
  - Sorted by kernel subsystem and topic

- https://lwn.net/Kernel/Index/

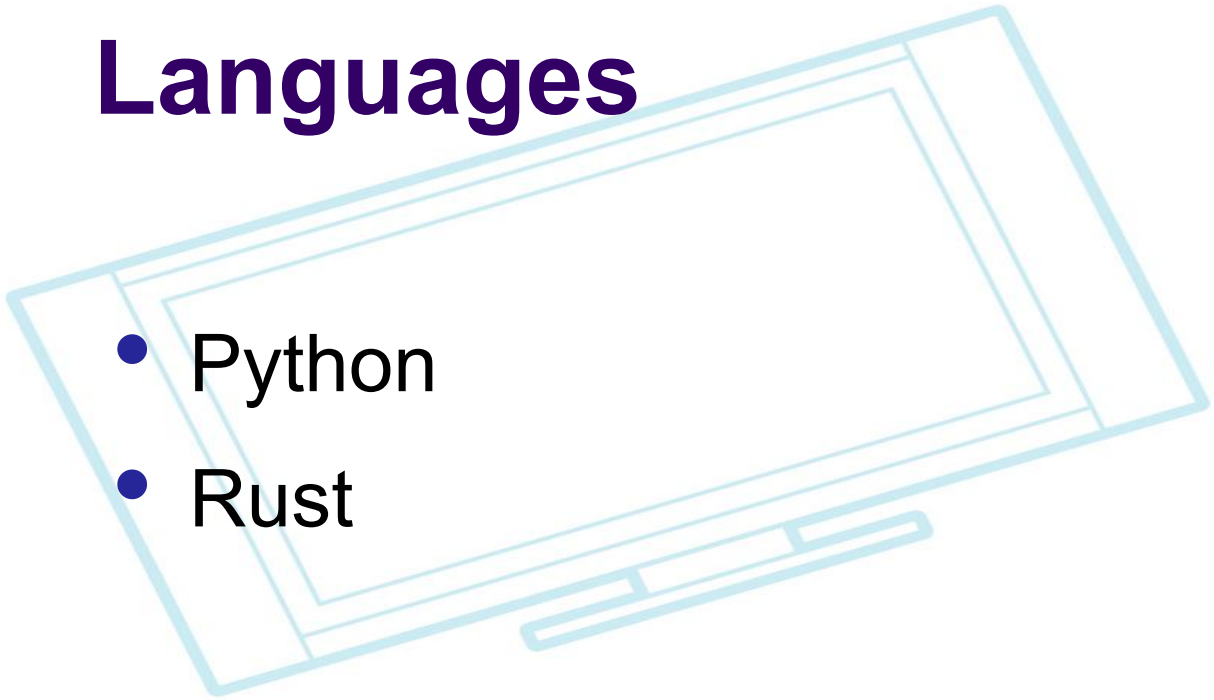


Boot Time reduction

- Resurrection of Ureadahead (as an upstream project)
  - Ureadahead allows to pull pages into memory so they are already in the page cache when needed by a process
  - Has been used for years by Chromebook team (since 2009), but upstream went inactive
    - Want to revive public, upstream project
  - Presentation at ELC 2023: https://elinux.org/images/5/5b/Ureadahead_resurection.pdf
    - by Steve Rostedt
  - Video - https://youtu.be/HwdWKMxM83E

Languages

- Python
- Rust



Languages - Python

- Python 3.12 released in October, 2023
  - https://docs.python.org/3.12/whatsnew/3.12.html
  - Python 3.12 improvements
    - Typing improvements
    - os and pathlib performance improvements
- Python 3.13 will have a JIT (Just-in-time compiler)
  - See https://tonybaloney.github.io/posts/python-gets-a-jit.html

Languages - Rust

- Rust support continues to go into the mainline kernel
  - Finally have an example of a "real" driver in 6.8
    - Still only an example
  - Also have a (RFC for a) Rust implementation of Android's Binder (IPC mechanism)
    - See https://lwn.net/Articles/953116/
  - Still a big debate about whether this is positive or negative for future maintenance
    - See https://lwn.net/Articles/952029/
- Rust 1.76 released on Feb 8, 2024

Test Suites

- LTP
  - Linux Test Project
- kselftest
  - Lots of tests and test improvements for bpf, mm, resctrl, hid, xsk, networking, x86 features, powerpc, KVM, landlock and more
- Kunit
  - kunit tool improvements
  - Proposal to support device testing (see subsequent page)

Test Suites - LTP

- LTP = Linux Test Project
- Big project to test kernel from user-space
  - Maintained by SUSE
  - Consists of POSIX, Realtime, system-call tests, and others
- Latest release = LTP 20240129 release
  - New tests and fixes to tests
  - New "runltp-ng” renamed to "kirk"
    - New test execution manager (still experimental)
  - Experimental LTX program (from LTP 20230929 release)
    - Tiny binary that executes tests on a separate machine
  - See https://github.com/linux-test-project/ltp/releases

Test Suites - kselftest

- kselftest/kunit proposed changes to KTAP
  - KTAP = Kernel Test Anything Protocol
    - Is the standardized output for kernel tests
- Recent proposal to add meta-data to tests and KTAPv2
  - Kunit Attributes: set of well-known tags
    - speed (fast or slow) – indicating speed category of test
    - is_init – indicates scope of execution
    - test_params – indicates parameters used for test
  - Can filter tests at runtime or results at analysis-time
- See "Storing and Outputing Test Information: Kunit Attributes and KTAPv2" (Plumbers 2023 presentation)
  - See https://lpc.events/event/17/contributions/1527/

Test Suites - Kunit

- Recent proposal is for testing of devices
- Check results of probing devices listed in device-tree
- Check results of instantiating devices on discoverable busses
  - Tests attributes in sysfs for devices, using a per-board definition file
  - Is first hardware-specific testing proposal I've seen upstream
  - Requires a set of board/device mappings, that upstream doesn't want to maintain
    - Probably develop an out-of-tree repository for this

Test declaration for kernel sub-systems

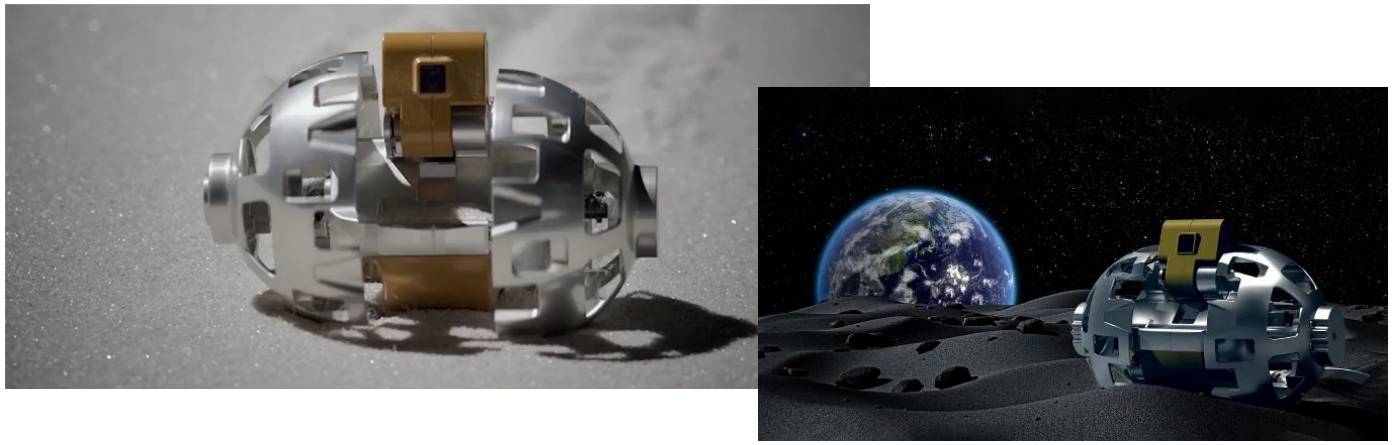
- Proposal for new system to specify a test for a sub-system
  - Add "V: <test-recommendation>" field to MAINTAINERS file
    - Can specify a test, or point to documentation about test to run
  - Suggested by Nikolai Kondrashov (RedHat testing group)
    - Still under development
- Eventually, may require patches to include attribute:
  - Tested-with: ...
  - Could include just test name, or reference to test results
- Goal is to allow:
  - Contributors to more easily test their patches
  - Maintainers can verify that patch doesn't break things

OpenWRT project designs its own hardware

- OpenWRT originally based on Linksys router software
  - Project is now 20 years old
- Project wants standard reference hardware
  - Making "OpenWRT One" board, with help from banana-pi org.
- Wants to make a fully open system
  - Users not stuck with proprietary firmware, anywhere in system
- See https://arstechnica.com/gadgets/2024/01/openwrt-now-20-years-old-is-crafting-its-own-future-proof-reference-hardware/

OSS on the Moon!

- Sora-Q transformable Lunar Rover (Also known as LEV-2)
  - Landed on the moon on the SLIM mission, by JAXA, on Jan 19, 2024
  - Developed by JAXA, Tomy, Sony, and Doshisha University
- Took this awesome picture of the SLIM lander
- OK – it's not Linux, but NuttX (but that's still open source)



Update on SFC vs. Vizio

- Lawsuit is still ongoing
- Is important, because SFC is asserting a novel interpretation of GPL rights
  - 3rd party beneficiary rights
    - which would allow any 3rd party to enforce the license
  - GPL is a contract, not a license
- Latest update:
  - Judge denied Vizio motion for summary judgement (Jan 3, 2024)
  - Appears to interpret GPL as a contract (as SFC asserts)
    - no "preemption" by copyright law (no removal to federal court)
  - See https://sfconservancy.org/news/2024/jan/03/vizio-sj-rejected/
  - Trial likely in June, 2024
- Random note: Walmart is trying to acquire Vizio

Embeded Linux Leadership Summit 2023

- Meeting of Embedded Linux ecosystem stakeholders
- Invitation-only event, with:
  - Product companies (Sony, Google, Amazon)
  - Processor vendors (ARM)
  - Trade associations (LF, Linaro)
  - Project leaders (AGL, CIP, KernelCI, Zephyr, RT Linux, Yocto)
  - Consulting companies (Baylibre, Collabora, Bootlin, Pengutronix)
- Discuss status of ecosystem, and technology areas that need work

Issues From Embedded Linux Leadership Summit 2023

- Security is an ongoing concern
- OTA updates
- Long-term support
- Heterogeneous core support
- Shared testing
- Safety critical / certification
- Standardization of HW components
- AOSP competition
- Lack of investment in infrastructure/ tools/ upstreaming
  - (not enough contributions)
- RT marketing
- Upstream AI/ML accelerators
  - Support for AI processing units (APU)

Plumbers Embedded Linux BOF

- Session at Linux Plumbers Conference to discuss issues with embedded Linux
  - Slides: https://lpc.events/event/17/contributions/1549/attachments/1344/2692/Embedded-Linux-BOF-2023-11-LPC.pdf
  - Video: https://youtu.be/1sIW64Qip-I
- Summary of major topics discuss in next few slides

Boot time discussion topics

- Coming out of low power state (suspend/resume)
  - Use Suspend/Resume (or unhibernate) instead of cold boot
- Android has a slow cold boot, and could use resume from flash (rather than cold boot from flash)
- Device links in device tree helps reduce boot time by lowering the number of deferred probes
- TI divided a network driver into early and late initialization
- Loading and authentication of firmware takes a lot of time
  - Would be nice to offload this (separate it from Linux startup)

System Size

- Arnd asks if 32-bit is being less used
  - But everyone in the room said that they have used 32-bit in the last year
  - For new processors, there's a huge trend to move away from 32-bit
- Linux fits just fine in smallest purchasable DRAM
  - Other Oses (such as Zephyr) should be used for sub-8M systems
  - Linux has lost markets where only SRAM is used (sub-2M)
- RISC-V supports 32-bit (but with smallest memory of 64M)

Linux Foundation projects

- Linux Foundation
  - Automotive Grade Linux (AGL) – handles automotive vertical
  - Civil Infrastructure Platform (CIP) – handles support longevity
  - Core Embedded Linux Project – is shutting down
  - DroneCode – handles drone vertical
  - ELISA – handled issues with safety certification and standards
  - KernelCI – handles automated testing (for upstream)
  - OpenChain – handles issues with entities in the supply chain
  - OpenSSF – working on security throughout OSS ecosystem
  - Yocto Project – build system for embedded OSS (not just Linux)

Automotive Grade Linux (AGL)

- Latest release = Prickly Pike (16.0)
  - Continued evolution of the Flutter support (by Toyota)
    - Flutter reference apps
    - Flutter workspace automation
  - Chromium Embedded Framework (CEF) available as a build option
  - Instrument cluster container improvements and demo
  - Systemd unit based application activation (tech. preview)
- Based on Yocto 4.0 (kirkstone) release
- Rust meta-layer for Yocto Project
  - Enables the latest Rust version to be used with AGL
  - It was upstreamed to Yocto Project as well
- Check out Walt Miner's talk last week at OSSJ for more info

Civil Infrastructure Platform

- Added 6.1-cip kernel version for super-long-term support
  - All CIP kernels are supported for at least 10 years
- Worked on the IEC 62443 security standard
  - International series of standards for cybersecurity in automation and control systems

DroneCode

- Manages several OSS projects in the drone ecosystem
  - PX4 – open source autopilot software
  - QGroundControl – ground control station software
  - MAVLink – lightweight messaging protocol
  - Pixhawk – open hardware standard for flight management units

ELISA

- ELISA = Enabling Linux in Safety Applications
- New 2023 seminar series about various safety-related topics
- Aerospace Workgroup
  - Working to identify challenges to adopting Linux in aerospace
- Medical Workgroup
  - Published methodology to trace specific workloads to identify kernel sub-system dependencies (for medical applications)
- Published ks-nav tool
  - Perform analysis of Linux kernel according to System-Theoretic Process Analysis (STPA) methods
    - See https://elisa.tech/blog/2023/06/05/diving-into-the-kernel-introducing-ks-nav-tool-set/
- Created a reference system with Linux, Xen and Zeph
  - Worked on CI tools

OpenChain

- OpenChain – helps with supply-chain issues
- Standards:
  - Open source license compliance standard ISO/IEC 5230
  - Security assurance program
- Finalized ISO/IEC 18974 standard for security assurance
  - Helps organizations define processes to check OSS for known security vulnerability issues (like CVEs, GitHub alerts or package manager alerts)
  - Identifies security process, roles and responsibilities, etc.
  - Should be published as a formal ISO standard by now (or soon)